

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.
- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.
- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.
- This document is paginated as submitted by the original source.
- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Thermal Power Systems
Small Power Systems Applications Project

Siting Issues
for Solar Thermal Power Plants
With Small Community Applications

(NASA-CR-15820) THERMAL POWER SYSTEMS SMALL
POWER SYSTEMS APPLICATION PROJECT: SITING
ISSUES FOR SOLAR THERMAL POWER PLANTS WITH
SMALL COMMUNITY APPLICATIONS (Jet Propulsion
Lab.) 45 p HC A03/MF A01

N79-22629

Unclas
25096

CSCI 10B G3/44



February 1, 1979

Prepared for
U.S. Department of Energy
by

Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

(JPL PUBLICATION 78-75, REVISION 1)



Thermal Power Systems
Small Power Systems Applications Project

Siting Issues for Solar Thermal Power Plants With Small Community Applications

H. J. Holbeck
S. J. Ireland

February 1, 1979

Prepared for
U.S. Department of Energy
by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California

(JPL PUBLICATION 78-75. REVISION 1)



Prepared by the Jet Propulsion Laboratory, California Institute of Technology,
for the U.S. Department of Energy by agreement with the National Aeronautics
and Space Administration.

The JPL Solar Thermal Power Systems Project is sponsored by the U.S.
Department of Energy and forms a part of the Solar Thermal Program to
develop low-cost solar thermal electric generating plants.

This report was prepared as an account of work sponsored by the United States
Government. Neither the United States nor the United States Department of
Energy, nor any of their employees, nor any of their contractors, subcontractors,
or their employees, makes any warranty, express or implied, or assumes any
legal liability or responsibility for the accuracy, completeness or usefulness of
any information, apparatus, product or process disclosed, or represents that its
use would not infringe privately owned rights.

ABSTRACT

Technologies for solar thermal plants are being developed to provide energy alternatives for the future. Implementation of these plants requires consideration of siting issues as well as power system technology. While many conventional siting considerations are applicable, there are also a set of unique siting issues for solar thermal plants. Early experimental plants will have special siting considerations.

This report considers the siting issues associated with small, dispersed solar thermal power plants for utility/small community applications of less than 10 MWe. Some specific requirements refer to the first engineering experiment for the Small Power Systems Applications (SPSA) Project.

The first two sections of the report provide background for the subsequent issue discussions. The introductory section describes the SPSA Project and the requirements for the first engineering experiment and gives the objectives and scope for the report as a whole. A brief overview of solar thermal technologies is followed by a discussion of some technology options.

The siting issues themselves are discussed in the remainder of the report in three categories: (1) system resource requirements, (2) environmental effects of the system, and (3) potential impact of the plant on the environment. Within these categories, specific issues are discussed in a qualitative manner. Examples of limiting factors for some issues are taken from studies of other solar systems.

The report has been revised primarily to reflect the current program plan for Engineering Experiment #1 (EE1) and to incorporate technology information from the EE1 Phase 1 system definition studies.

ACKNOWLEDGMENTS

The authors acknowledge the participation of a number of individuals in the preparation of this report. Technical inputs to various sections were contributed by Steven A. Bluhm, Joseph G. Herrera, Charles F. Hutchinson, McGregor S. Reid, Phillip C. Walden, and James R. Womack. The review and editing, essential to the final form of the report, were supported by Richard L. Anglin, Jr., William J. Carley, Richard Case, Robert R. Ferber, Eugene A. Laumann, Lewis Leibowitz, and Alan T. Marriott. The efforts of all of these individuals are greatly appreciated.

CONTENTS

| | | |
|------|---|----|
| I. | INTRODUCTION ----- | 1 |
| A. | Background ----- | 1 |
| B. | Project Description ----- | 1 |
| C. | Objective and Scope ----- | 2 |
| D. | Approach ----- | 4 |
| II. | TECHNOLOGY OPTIONS ----- | 6 |
| A. | Background ----- | 6 |
| B. | Optional Solar Thermal Systems ----- | 8 |
| III. | SYSTEM RESOURCES ----- | 17 |
| A. | Insolation ----- | 17 |
| B. | Water ----- | 19 |
| C. | Construction Materials and Manpower ----- | 19 |
| D. | Land ----- | 20 |
| IV. | PHYSICAL ENVIRONMENT ----- | 22 |
| A. | Wind ----- | 22 |
| B. | Precipitation ----- | 23 |
| C. | Temperature and Air Quality ----- | 25 |
| V. | SOCIAL/INSTITUTIONAL ISSUES ----- | 26 |
| A. | Legal-Regulatory ----- | 26 |
| B. | Community/Regional Support ----- | 27 |
| VI. | SOLAR THERMAL POWER PLANT IMPACT ----- | 29 |
| A. | Ecological Impact ----- | 29 |

| | | |
|--------------------|---|----|
| B. | Microclimate and Air Quality ----- | 30 |
| C. | Water Use ----- | 31 |
| D. | Land Use ----- | 32 |
| E. | Community ----- | 33 |
| F. | Safety ----- | 33 |
| REFERENCES ----- | | 35 |
| BIBLIOGRAPHY ----- | | 36 |
| FIGURES | | |
| 1. | Schedule for the SPSA First Engineering Experiment (EE No. 1) for Small Community Applications ----- | 3 |
| 2. | Solar Thermal-Electric Conversion Subsystems ----- | 7 |
| 3. | McDonnell Douglas Small Central Receiver Concept ----- | 9 |
| 4. | Concept for a Small Electric Power System Module ----- | 9 |
| 5. | General Electric System Concept ----- | 11 |
| 6. | General Electric Proposed Collector Receiver/Boiler Assembly ----- | 11 |
| 7. | Simplified Process Flow Diagram, 1 MW Power Conversion ----- | 13 |
| 8. | Ford Aeronutronics Concept ----- | 14 |
| 9. | Ford Aeronutronics Power Module ----- | 14 |
| 10. | System Schematic ----- | 15 |
| 11. | Direct and Total Insolation ----- | 18 |

TABLES

| | | |
|----|--|----|
| 1. | Siting Issue Summary ----- | 5 |
| 2. | Soil Susceptibility to Wind Erosion (Ref. 8) ----- | 24 |
| 3. | Regulatory Issues ----- | 26 |

I. INTRODUCTION

A. BACKGROUND

Technologies for solar thermal power plants are being developed on an accelerated basis to provide alternatives for future energy needs. Use of these technologies requires suitable sites. Acquisition of the most desirable sites will increasingly be in competition with other potential uses as population and industrial growth continues. There is also an increasing public and governmental awareness of alternative land uses and environmental impacts.

Some of the siting issues for a solar thermal power plant are common to a wide variety of development projects while others are unique to the requirements and effects of this new technology. All developments must consider physical and engineering characteristics, such as topography, soils, geology, meteorology, and construction costs. Another important consideration is the availability of the prospective site from the perspective of local zoning ordinances and regulatory agency requirements. In addition, the environmental impact of development projects on both the natural environment and the socio-economic environment has come to the forefront since the passage of the National Environmental Policy Act (NEPA).

The siting of conventional electrical generation facilities, both nuclear and fossil fueled, is strongly affected by considerations of safety, pollution, and aesthetics. Solar thermal-electric power plants minimize some of these effects while introducing new siting limitations of their own. The availability of adequate insolation is an obvious siting factor as is the availability of adequate land. Small, dispersed solar facilities should be close to the power demand to minimize transmission costs. Early experimental plants will have additional siting considerations to satisfy experimental objectives.

B. PROJECT DESCRIPTION

1. General Project Background

The Small Power Systems Applications (SPSA) Project is an element of the Thermal Power Systems Branch of the Department of Energy (DOE). The overall goal of Small Power Systems Applications (SPSA) project is to establish technical, operational and economic readiness of small power systems less than 10 MWe in size. The project will develop systems to the point at which subsequent commercialization activities can lead to successful market penetration. The project technical approach is centered around engineering system experiments and demonstrations of appropriate technologies and applications.

2. First Engineering Experiment System Development

The first engineering experiment, with a capacity of approximately 1-MWe, will be designed and constructed in a three-phase program

as shown in the schedule in Figure 1. Three technology approaches are being considered in the system definition phase. (Technology options for solar thermal power plants are described in Section II.)

At the end of the Phase I systems definitions studies, the technology approach and a general system design for the experiment will be selected. The second phase will then include the preliminary design of the selected system as well as development and testing of components and subsystems. Final design, fabrication, installation, and testing will be accomplished in the third phase. Experimental operation is scheduled to begin in early 1983.

3. Siting for the First Engineering Experiment

The application for the first engineering experiment is defined as a small community with an electric utility demand load less than 100 MWe. Site selection will occur parallel to the development of the technological system. Participation requirements will be described in solicitation documents distributed to those expressing an interest in submitting a proposal. Site proposals submitted by interested groups will be evaluated by DOE, and from these a site will be selected for the first engineering experiment.

Because of a potentially large number of interested small communities proposals a section of the solicitation document will contain advisory qualification standards to describe a set of characteristics that every desirable site should possess. While the lack of some sub-set of these desirable characteristics will not exclude a site from consideration, this may result in a lower ranking in the site evaluation process. The function of these advisory qualification standards is to discourage proposal expenditures from potential site participants which do not have a good chance at a high ranking in the evaluation process.

The DOE will provide, under separate contract, for the construction, installation and testing of the experimental solar thermal power plant, except for distribution system elements. The plant design will be based on a point focusing solar thermal technology in which solar energy is concentrated by collectors that both track and focus to operate one or many high-temperature heat engines. (A background technology discussion is provided in Section II.) Several technology options are being investigated prior to final system design. This experimental plant is intended to augment an existing utility system by supplying power for peak-to-intermediate loads. However, an important project objective is to obtain experimental information and this may cause the production of electricity to be somewhat intermittent, especially during the first year of experimental operation.

C. OBJECTIVE AND SCOPE

The primary objectives of this study are to identify and discuss the issues associated with siting a solar thermal power plant with a

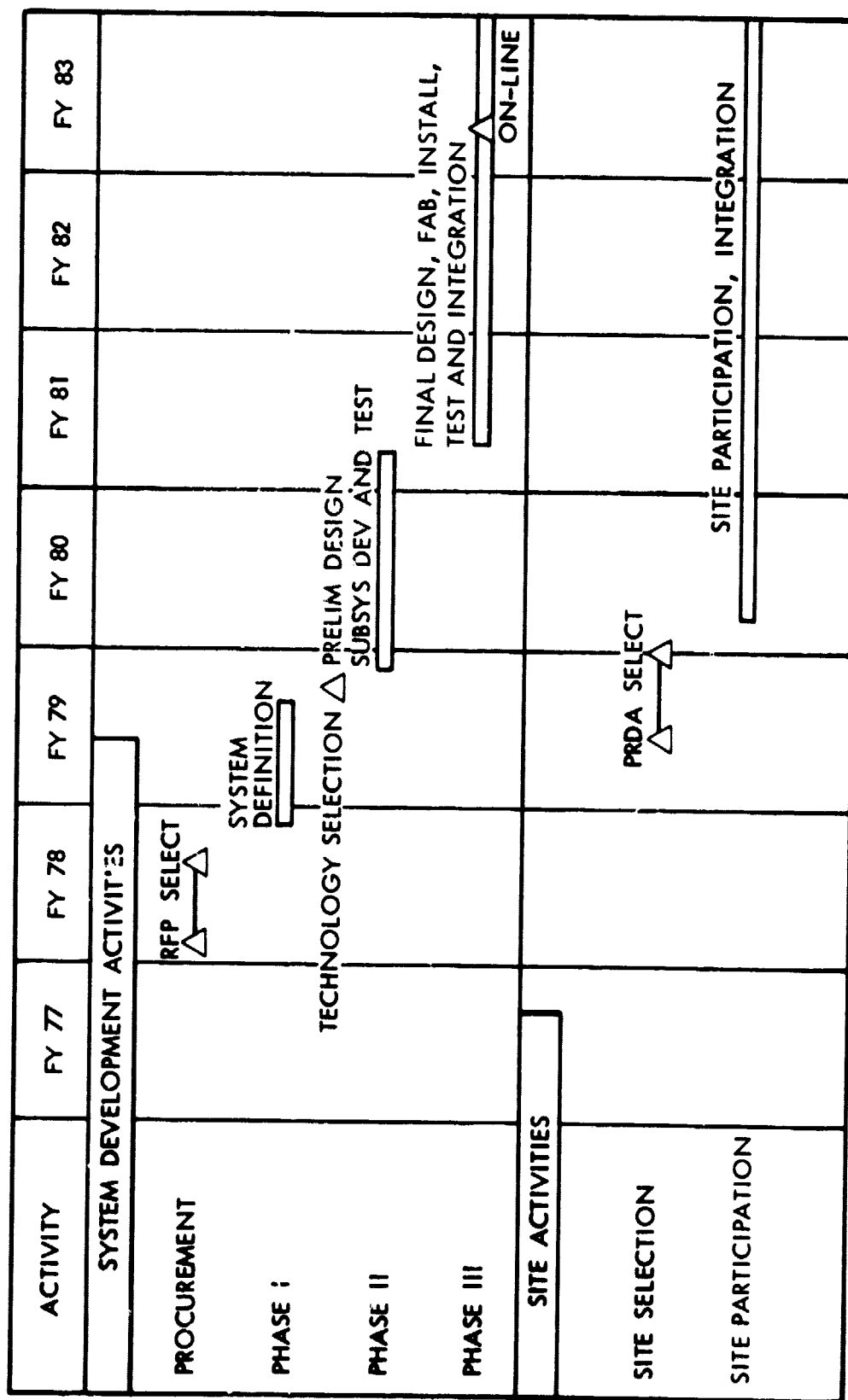


Figure 1. Schedule for the SPSA First Engineering Experiment (EE No. 1) for Small Community Applications

utility/small community application and to define areas requiring further study. This study effort is a part of the siting activity for an experimental 1 MWe power plant, and specific examples in the report are based on siting requirements for this experiment. However, most issues are expected to have a more general application.

This report provides a qualitative discussion of siting issues. Its intended use is to provide a preliminary basis for the preparation of more detailed site requirements and site evaluation factors. It may also provide a useful background for potential site participants. Siting issues are discussed from both power system and site participant viewpoints.

D. APPROACH

Siting issues for solar thermal power plants were identified using conventional siting requirements as a baseline. Significant issues were then considered in conjunction with the requirements and impacts of solar thermal-electric technology. The resulting siting issues are similar to those for conventional generation facilities with the exception of their groupings, the perspective in which they are viewed, and the emphasis placed on them. Documents referenced in this study are included in the bibliography. Additionally, much information of value was obtained at the Small Power Systems Solar Electric Workshop held in Aspen, Colorado, October 10-12, 1977 (Ref. 1).

Relationships between solar thermal-electric power plants and their sites may be categorized in terms of effects of the site on the plant and effects of the plant on the site. Effects of the site on the plant will be discussed by identifying the resources and site characteristics desirable for construction, operation, and maintenance of a solar thermal-electric power plant. The effects of the plant on the site will be discussed by identifying the impacts plants may have on their sites, and how these site impacts may result in construction delays and even development termination. This report describes the relationship between solar thermal-electric power plants and their sites and delineates the information that should be assembled in order to make informed siting decisions. Table 1 summarizes some of the basic siting issues. The most important issues are indicated by asterisks.

Table 1. Siting Issue Summary

| | |
|---|--|
| <u>SYSTEM RESOURCES</u> | |
| *Insolation | intensity and occurrence/time of direct component Measurement capability and/or data availability |
| *Water | Quantity available Quality |
| Construction Materials and Manpower | Local availability |
| *Land | Adjacent land uses Stability Slope Site preparation Soil type Access |
| <u>PHYSICAL ENVIRONMENT</u> | |
| *Wind | Average velocity and occurrence/time Extreme velocity and occurrence/time |
| Precipitation | Types Averages and extremes Erosion and floor occurrence |
| Temperature | Averages and extremes Degree change/time |
| Air Quality | Air Quality Summary |
| <u>SOCIAL/INSTITUTIONAL ENVIRONMENT</u> | |
| *Legal-Regulatory | Regulation complexity Regulatory impediments Experience of local regulatory agencies with large developments |
| *Community/Regional Support | Public opinion Media availability Public access Resources Socio-economic stability Managerial experience and innovation with large developments |
| *Utility Interface | Grid flexibility Convenient transmission line tie-in |
| <u>SOLAR THERMAL POWER PLANT IMPACT</u> | |
| Microclimate | Albedo changes Meteorological change |
| *Water Use | Compatibility Depletion Other users |
| *Land Use | Compatibility Zoning Access and Utility Easements |
| Ecology | Endangered species Alter community structure |
| Community | Public services strained Nuisance Aesthetic |
| Safety | Malfunctioning tracking mechanisms Nuisance Glare hazard Exposure to toxic substances High-temperature pipelines |

II. TECHNOLOGY OPTIONS

A. BACKGROUND

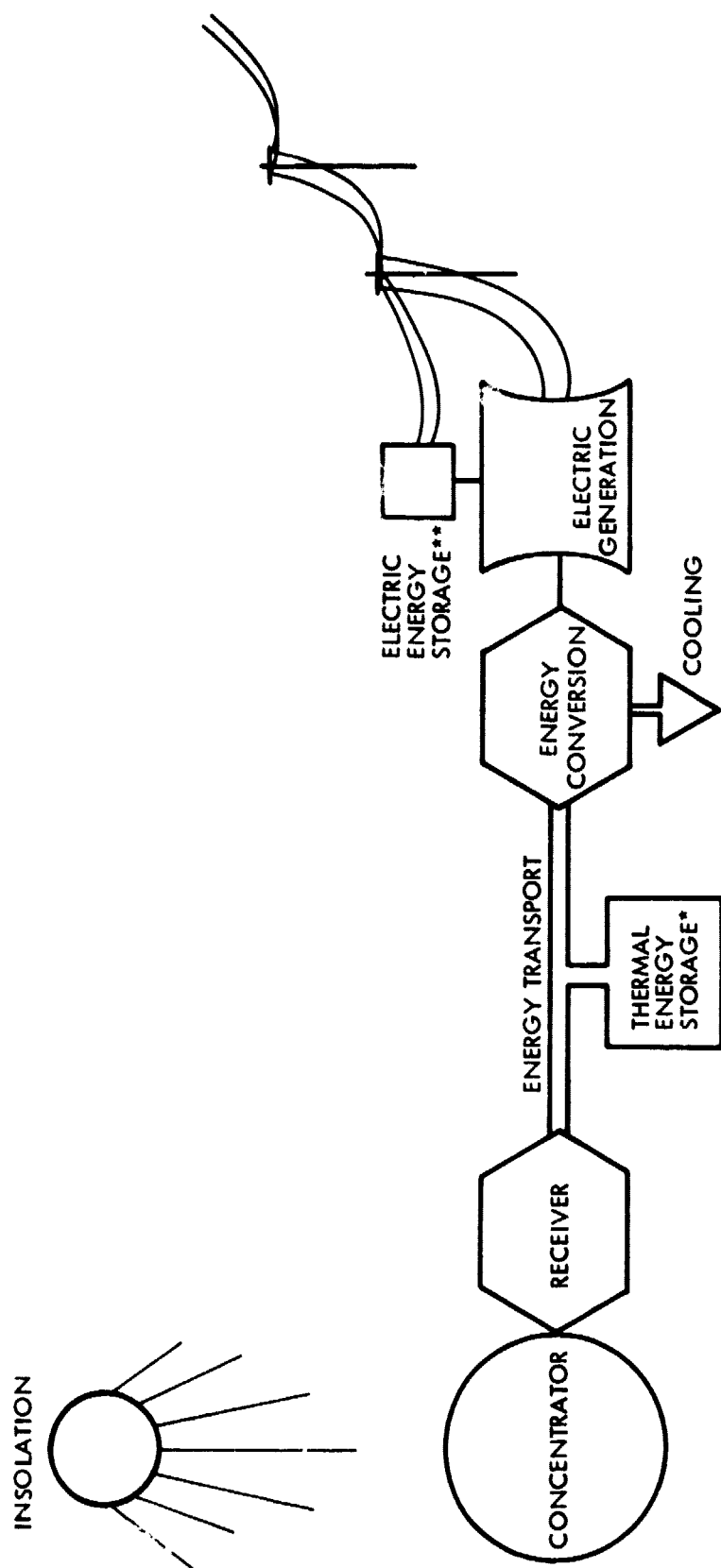
This brief description of solar thermal power technology is included to provide background information relative to the siting issues identified. There are a variety of ways to utilize solar energy (insolation). Flat plate collectors utilize both the direct and diffuse components of the total available insolation. On cloudy days the amount of available insolation is considerably reduced, but some of the diffuse component is available due to scattering.

Solar thermal power systems collect and concentrate the sun's radiant energy to heat or vaporize a working fluid. This thermal energy may be used either directly or to drive a heat engine. Electricity can then be generated from the resulting mechanical energy. Acceptable engine efficiency requires the high temperatures associated with high concentration ratios. The plant design for EEL is limited to high concentration point focusing systems with two-axis tracking mechanisms.

The key elements of a solar thermal power system are shown schematically in Figure 2. Solar energy is collected by a tracking concentrator, which focuses energy on a receiver. The working fluid in the receiver is raised to a high temperature and is then transported to a heat engine, which converts the thermal energy into mechanical energy from which electricity can be generated. Energy storage may be incorporated as thermal storage in the thermal transport system, as mechanical storage following conversion or as electrical storage following generation. These functions must interact effectively as a total system to attain high overall plant efficiency.

Some early solar thermal plants may be hybrid-fired pending the development of efficient storage techniques. These plants could utilize fossil fuels when there was inadequate insolation but would be operated to maximize usage of the available solar resource.

Heat engines for a solar thermal power plant produce mechanical work from a heat flux. The heat flows from a high-temperature source through the engine, thereby converting a fraction of the heat into mechanical work while rejecting the remainder at a lower temperature. The thermal efficiency of an engine may be defined as the mechanical work output divided by the heat input. The theoretical maximum efficiency of a heat engine depends on the ratio of the input and rejection temperatures. Achievement of high engine efficiency requires not only a high temperature ratio but also internal processes to exploit this temperature ratio without introducing excessive thermodynamic losses. The lower end of the temperature ratio is limited by the heat rejection, or cooling, subsystem while the upper end is limited by the concentration ratio and receiver material capabilities.



*Storage prior to conversion may be either thermal or chemical
 **Storage after conversion may be either electric or mechanical

Figure 2. Solar Thermal-Electric Conversion Subsystems

Heat engine efficiency is important from three perspectives. First, high efficiency yields a given power output with a lesser amount of solar energy. This, in turn, allows a smaller collector field, thereby saving both collector cost and land area. Second, higher efficiency can provide for savings in the receiver, energy transport, and energy conversion (heat engine) subsystems. Third, engine efficiency directly affects the requirements for waste heat rejection, which can be considered to be the inverse of the work output equation.

All heat engines require cooling to reject the thermal energy not used in energy conversion. The cooling subsystem controls the lower end of the engine temperature ratio and hence affects engine efficiency. The type of cooling system used depends on the type of engine, the amount of cooling required, cost, and the availability of a cooling medium. Some types of cooling systems are: flow-through, evaporation ponds, wet and dry mechanical draft towers, and wet and dry natural draft towers. Cooling requirements can be quite large. The make-up water required for evaporative cooling in a 1-MWe plant may exceed 30m^3 (1000 ft^3) per day.

B. OPTIONAL SOLAR THERMAL SYSTEMS

This section is excerpted from a report titled, "An Overview of Power Plant Options for the First Small Power System Experiment: Engineering Experiment Number 1" JPL-5103-38 by Philip Walden. (Ref. 2) The three selected concepts for Phase I studies are included to provide a general idea of the solar thermal technologies being considered for EE1. Final designs may differ significantly from these concepts.

1. McDonnell Douglas Astronautics Company

a. Proposed McDonnell Douglas System Description. The McDonnell Douglas small central receiver concept is pictured in Figure 3. The proposed complete system is made up of four subsystems, the collector, power conversion, energy transport and energy storage subsystems, as shown in Figure 4.

The collector consists of a concentrator and a receiver. The concentrator is comprised of a field of approximately 160 two-axis tracking reflectors, called heliostats, which direct incident solar radiation to a tower mounted receiver. The heliostat field is located north of the receiver tower, and requires about 8 acres of land. The heliostat is based on the design being developed by McDonnell Douglas for the DOE Central Power Program, 10-MWe central receiver pilot plant. Each heliostat is mounted on a pedestal with azimuth and elevation drives. The reflecting surface consists of rectangular mirrors mounted on either side of the pedestal, as shown in Figure 4, for a total of 38 square meters of reflecting area for each heliostat. The heliostat field utilizes an open loop control system to track the sun with each heliostat controlled by the central control unit. The receiver is mounted on an open frame tower approximately 46 meters high supported by guy wires. Solar radiation concentrated by the heliostat field is

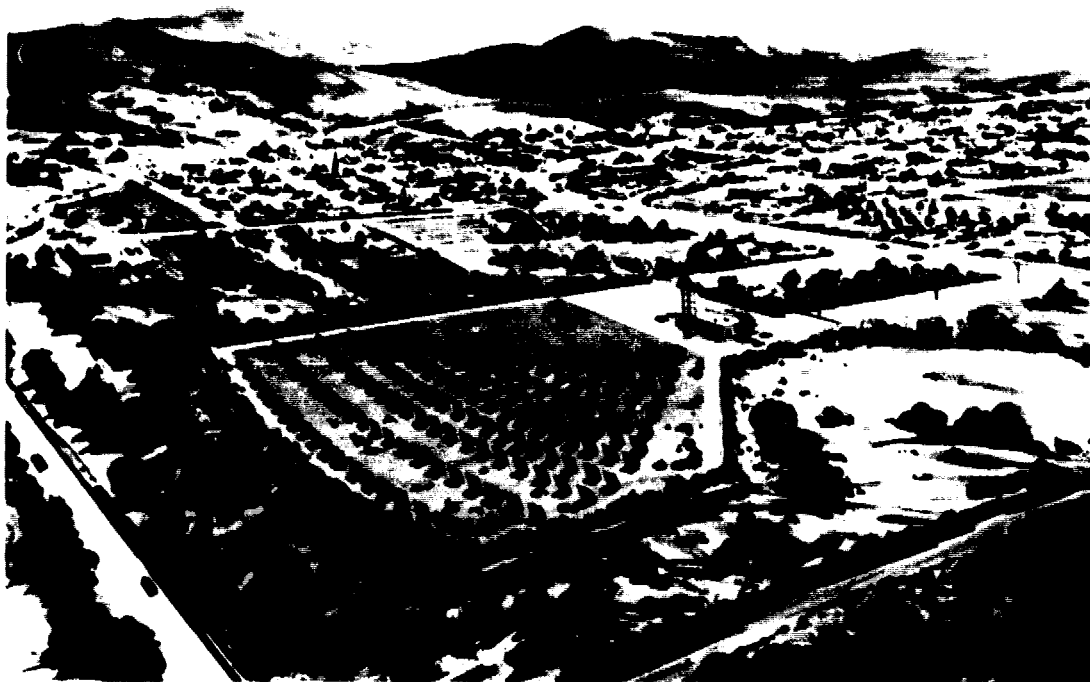


Figure 3. McDonnell Douglas Small Central Receiver Concept

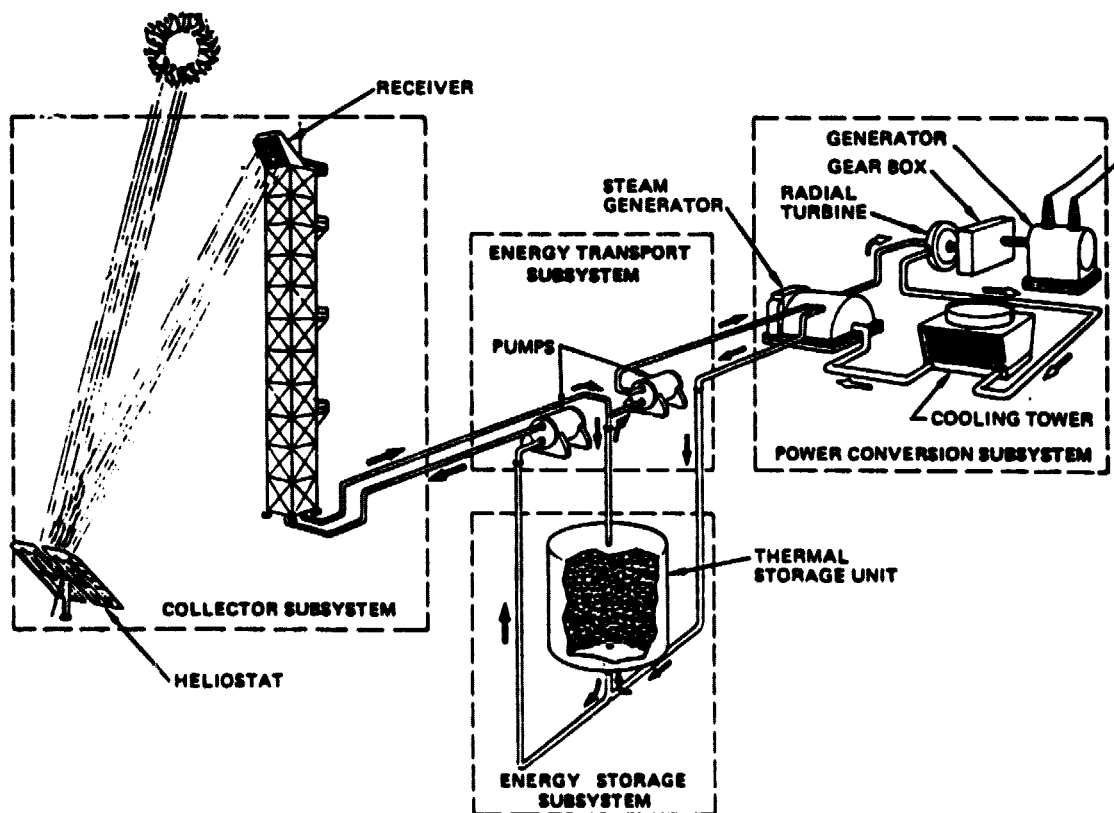


Figure 4. Concept for a Small Electric Power System Module

absorbed by two series of exposed pipes within the receiver, heating the Hitec fluid used in the energy transport subsystem.

The energy transport subsystem utilizes Hitec fluid, a mixture of salts with a low melting temperature, to transport thermal energy from the receiver to the power conversion subsystem. As shown in Figure 4, the hot Hitec, at about 500°C (930°F), is pumped to either the energy storage unit for use later, or to the steam generator unit to produce steam. Cold Hitec, at about 288°C (550°F), is pumped back to the receiver.

Steam produced from the steam generator at approximately 482°C (900°F), drives a steam Rankine cycle radial outflow turbine which in turn drives a gearbox and electrical generator to produce electricity. Waste heat from the turbine is rejected by a wet cooling tower. The nominal output of the power conversion unit is 1.1 MWe of which 0.1 MWe powers parasitic loads such as pumps and controls.

The energy storage unit acts as an accumulator, storing thermal energy produced in excess of the energy needed by the power conversion subsystem. The stored energy is used when the power conversion subsystem requires more energy than the receiver can deliver during cloud blockages or at sunset. The storage unit may consist of a large tank with 75% of its volume filled with a rock/sand mixture. The sensible heat of the rock/sand mixture stores the thermal energy as the hot Hitec mixture is pumped through the storage tank. The tank, for the baseline system, is large enough to hold 9 MW-hr of thermal energy which can run the solar plant for 3 hours at the rated power of 1 MWe.

2. General Electric

a. Proposed General Electric System Description. The General Electric system concept, pictured in Figure 5, is comprised of a collector field of 150 two-axis tracking parabolic dish reflecting concentrators. Each concentrator is enclosed with an air-supported transparent enclosure to eliminate wind loading and reduce weather induced mirror degradation of the concentrator. Each dish concentrates incident solar radiation on a ball shaped heat pipe receiver-boiler mounted at its focal point. Steam from the receiver-boilers is transported to the central power conversion unit by vacuum insulated pipes. The General Electric system attempts to minimize field construction costs by reducing the field installation time.

Each concentrator is mounted on a single pipe pedestal mount at approximately 40 foot intervals and is pivoted through its center of gravity located at its focal point. Figure 6 depicts the construction of a dish. Twenty-eight parabolic segments are mounted on a ring support structure to form a dish with a diameter of about 8 meters. Each segment is fabricated from a $3/4$ " aluminum honeycomb sandwich core with a reflecting mylar surface. The total concentrator weight is approximately 500 lbs. Coarse tracking is controlled by a central computer with a closed loop sun sensor for precision tracking of the sun.

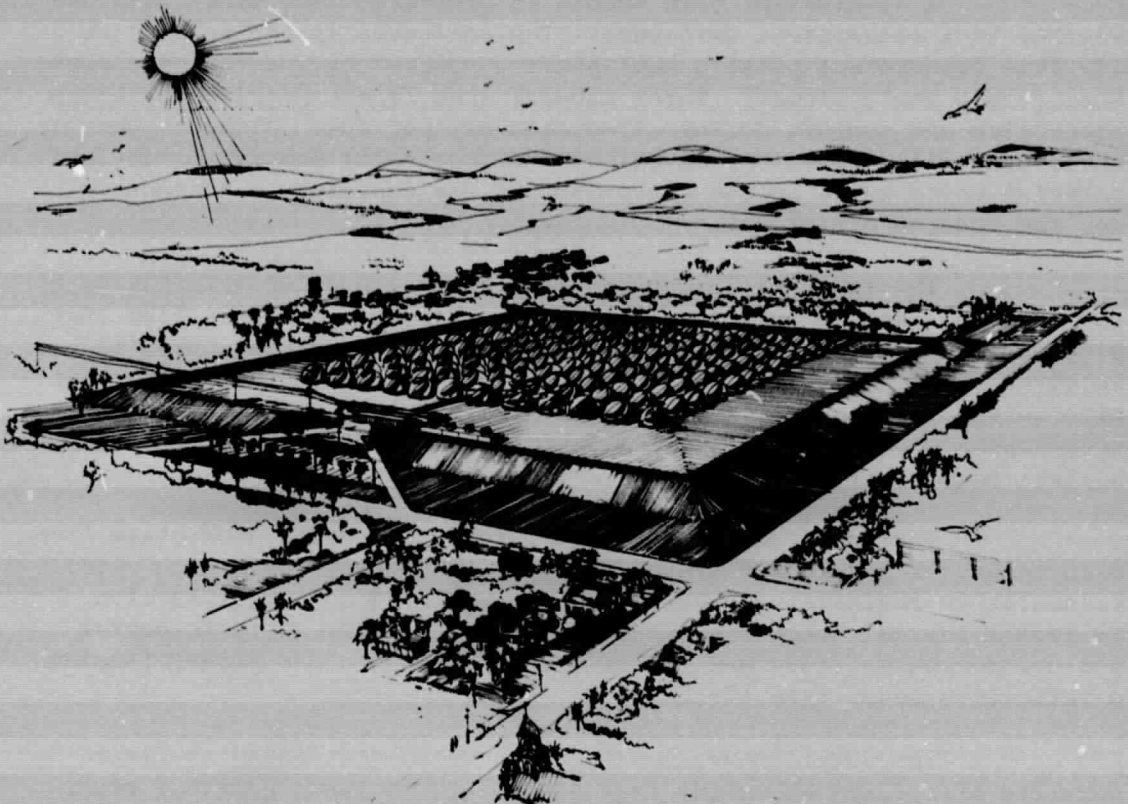


Figure 5. General Electric System Concept

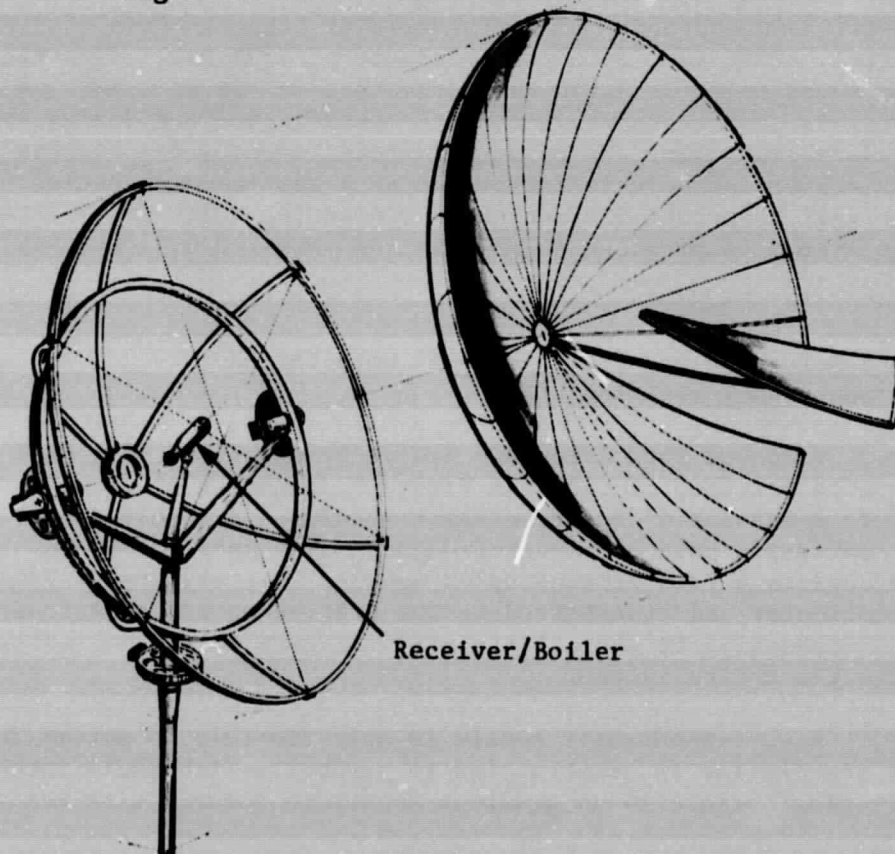


Figure 6. General Electric Proposed Collector Receiver/Boiler Assembly

A lightweight dish module is protected from wind loads and weather by a transparent enclosure. The enclosure is constructed of a flexible transparent plastic hemisphere supported by internal air pressure from a small blower. Three tubular step frames provide lightning protection and support during air-system-off periods. Although the enclosures will transmit only 86% of incident solar energy, weight and material costs saved on the concentrators are expected to compensate for the reduced efficiency.

The receiver is mounted in a fixed elevation orientation at the focus of the concentrator, as shown in Figure 6. A potassium heat pipe with a 8 in diameter ball shaped absorbing surface at the dish receives the concentrated solar energy. Heat is conducted up the heat pipe to a series of boiler tubes thermally coupled to the heat pipe. Superheated steam, at approximately 510°C (950°F), is produced from the boiler; feed-water to the boiler is at about 205°C (400°F).

The energy transport system collects superheated steam from each collector module and transports it to the power conversion unit; feedwater is redistributed back to each module in a similar fashion. To reduce thermal losses on the long runs of piping, 20 ft feedwater and steam pipe sections are sealed within a long vacuum jacket forming a reflective Dewar-type flask.

The power conversion unit, shown schematically in Figure 7, consists of a 1,235 kW marine type steam turbine, an electrical generator coupled to the turbine through a speed reducing gear box, and all the supporting components. The turbine inlet steam temperature is at approximately 482°C (900°F) with a pressure of 1200 psi. Electrical output is rated at about 1,140 kWe with a net output of 1 MWe. A steam accumulator is used to maintain turbine speed at no-load during intermittent cloud blockages. Waste heat is rejected by a dry cooling tower. The power conversion unit is integrated as a complete submodule. The module is rail transportable and skid mounted for quick installation. A storage system is proposed to achieve the required 0.4 capacity factor.

3. Ford Aerospace and Communications Corporation, Aeronutronics Division

a. Proposed Ford Aerospace System Description. The Ford Aeronutronics concept, pictured in Figure 8, consists of a collector field of 23 parabolic dish concentrator modules. A receiver unit and a power conversion unit are mounted on each dish near the focus. Figure 9 depicts a Ford Aeronutronics module. Electricity is generated at each collector and transported to the station power conditioning unit providing connection to the utility grid. Figure 10 schematically represents the entire system.

Each concentrator module is approximately 16 meters in diameter and similar in construction to parabolic dish radio antennas. The reflecting surface is an aluminum substrate covered with metallized

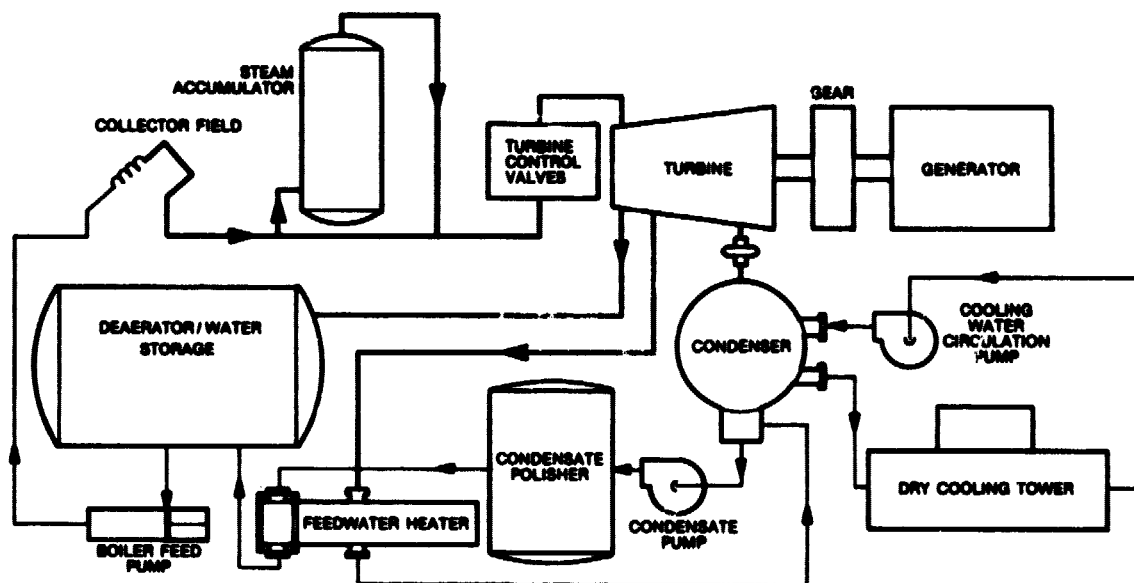


Figure 7. Simplified Process Flow Diagram, 1 MW Power Conversion

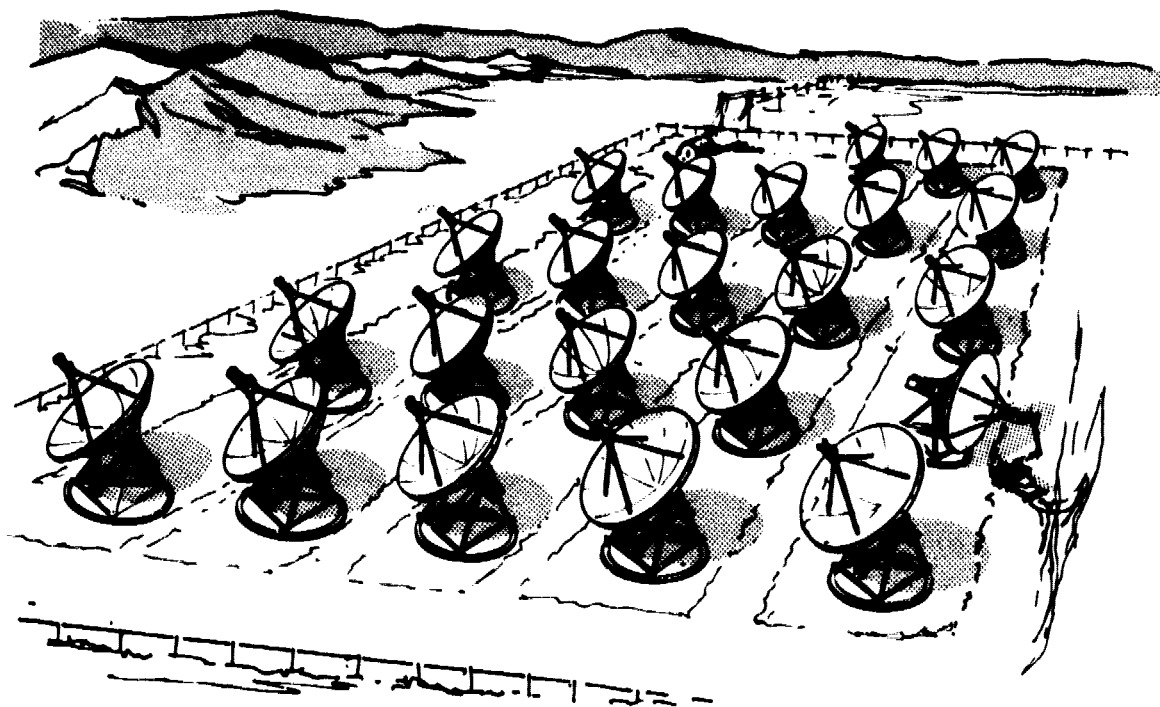


Figure 8. Ford Aeronutronics Concept

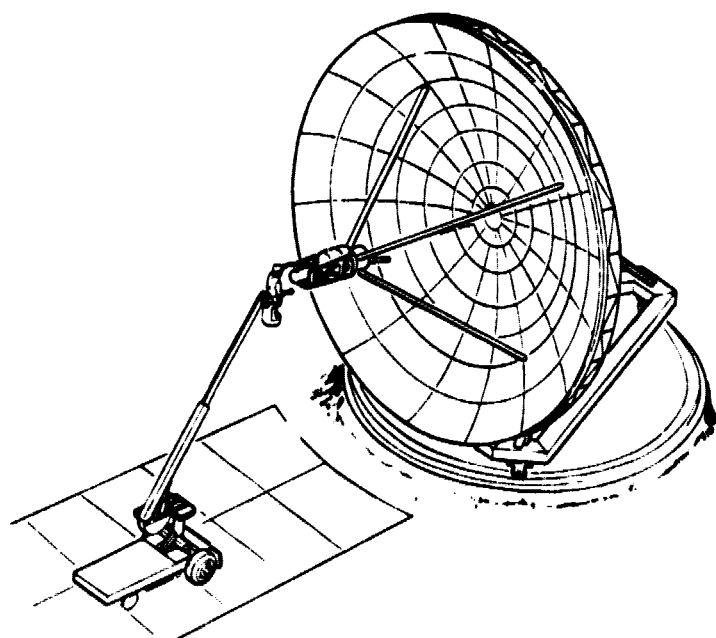


Figure 9. Ford Aeronutronics Power Module

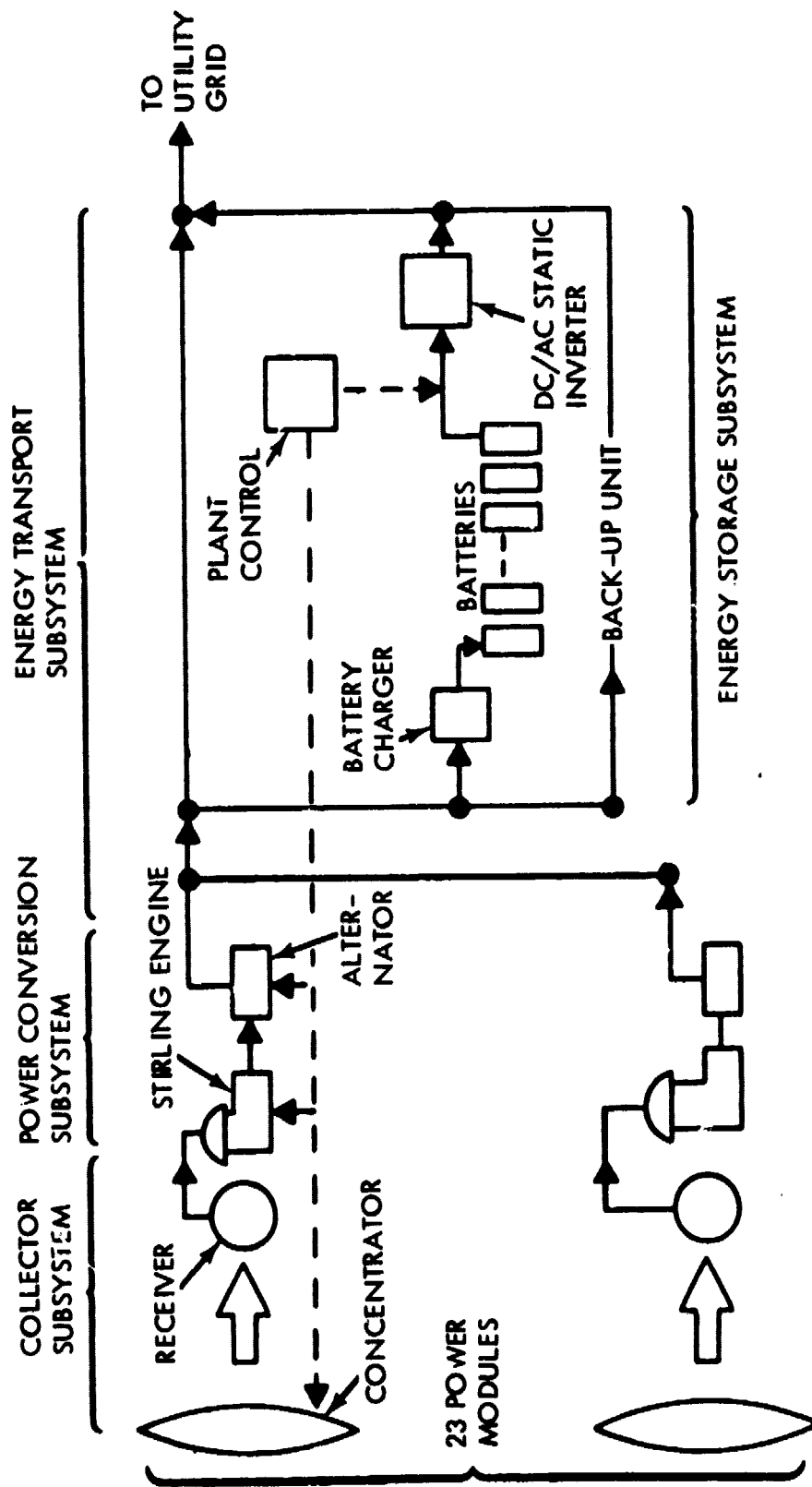


Figure 10. System Schematic

acrylic tape. The concentrator is mounted on a circular wheeled track for azimuth tracking. A ball and screw jack provides elevation tracking. A sun sensor provides closed loop tracking control. Each module is located in the collector field to minimize sun blocking by other collectors.

The receiver unit and power conversion unit are both mounted near the concentrator focus on a quadripod structure. The cylindrical cavity type receiver utilizes sodium as a heat transfer medium and operates at about 750°C (1382°F).

The power conversion unit consists of a reciprocating Stirling cycle heat engine with gear box and alternator to produce electricity. The proposed heat engine is a P-75 Stirling cycle engine produced by United Stirling of Sweden (USS), modified for a sodium heat source and using helium as a working gas. Waste heat is conducted down the quadripod to a conventional water/ethylene glycol heat exchanger mounted behind the concentrator reflecting surface. The net electrical output is 50 kWe per module.

Twenty two modules are required to achieve rated power of 1 MWe and a lead-acid battery storage subsystem are required to achieve a 0.4 plant capacity factor. AC-DC and DC-AC convertors are used to connect the batteries to the utility grid.

III. SYSTEM RESOURCES

This section of the report identifies siting issues that arise from the resource requirements of solar thermal-electric power plants. In previous sections the technology options for the first engineering experiment were described. With that knowledge the reader will be able to see why the resources discussed in this section are necessary and thus have a better understanding of the siting issues that arise as a result of resource requirements.

The resources needed to construct and operate solar thermal power plants include: (1) appropriate quantity and quality of insolation, (2) adequate water supply, (3) construction materials and manpower, and (4) suitable land area.

A. INSOLATION

Inbound solar radiation (insolation) that has passed through the earth's atmosphere has a direct component and a diffuse component. Direct insolation is primarily visible radiation which has penetrated the atmosphere without being deflected. Diffuse insolation has penetrated the atmosphere but has been scattered by gas molecules, water droplets in clouds and dust particles. Clouds are capable of reflecting much radiation back into space allowing only reduced amounts of diffuse insolation to reach the earth's surface.

Solar thermal-electric technology requires high temperatures to achieve acceptable system efficiencies. The required temperatures can only be achieved by concentration. Diffuse insolation cannot be effectively concentrated and therefore solar thermal-electric systems can only operate on days when direct insolation is available, when skies are very sensitive to site specific atmospheric/meteorologic conditions. The impact of cloud cover on the quantity of insolation available to solar thermal-electric systems is illustrated in Figure 11.

Figure 11a. illustrates insolation under clear sky conditions when the direct component comprises most of the total insolation. The apparent discrepancy between the measured levels of total insolation, the sum of diffuse and direct insolation is a function of measurement technique. The direct insolation was measured by a heliometer, an instrument which is capable of tracking the sun throughout the day. Tracking capability maximizes the amount of direct insolation reaching the instrument because it allows the sun's rays to be intercepted perpendicularly. The total insolation, depicted by the lower solid curve, was measured by a pyranometer, an instrument fixed horizontal to the earth's surface. This instrument intercepted the sun's rays at an angle, and because of its fixed position the angle of interception varied as the sun crossed the sky. These different measuring techniques cause the tracking heliometer to measure an apparently higher insolation value compared to the pyranometer, except when both instruments are pointed directly at the sun, because of the cosine effect. This occurs even though the heliometer measures only the direct component of insolation and the

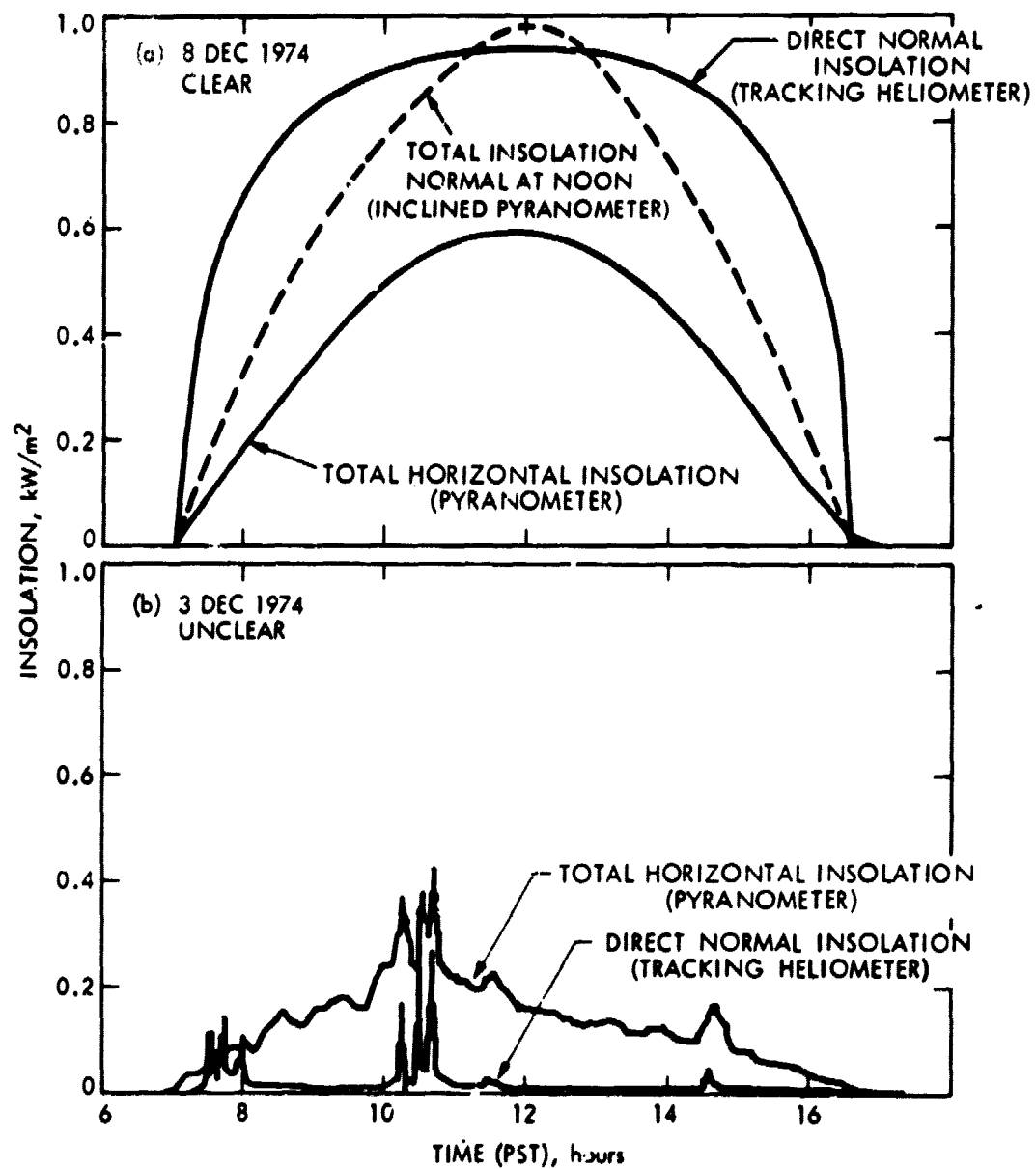


Figure 11. Direct and Total Insolation

pyranometer measures total insolation, both direct and diffuse. The dashed line indicating total insolation demonstrates the increase in the quantity of insolation which can be measured by inclining the pyranometer so that it is perpendicular to the sun's rays at noon.

Figure 11b. illustrates insolation under unclear sky conditions. In this case the direct component of insolation was reflected back into space by the cloud cover and only diffuse light was able to reach the instruments. Because the pyranometer is capable of measuring total insolation, and the heliometer is only capable of measuring the direct component, the pyranometer measured much higher insolation values. The performance of the tracking heliometer is closely related to the performance of solar thermal electric power plant collectors.

To fully evaluate a site for solar thermal-electric systems, the quantity of direct insolation available must be determined. However, insolation data such as those depicted in Figure 11 are not commonly collected. A general indication of regional insolation can be obtained from the U.S. Climatological Atlas. For site selection purposes insolation evaluation will be performed by the Government.

B. WATER

Solar thermal power plants, depending on design, may require water for cooling, make-up, maintenance, and energy transport. The requirement for cooling in solar thermal-electric power plants was described in the technology description section of this report. The amount of water required for cooling depends on the technology utilized.

Solar thermal power plants may also require water for energy transport. High water quality is required to avoid the deposition of impurities within transport pipelines. Solar thermal-electric systems using steam or hot water to drive turbines will require water to replace losses due to evaporation and cooling tower "blowdown."

Because high concentrator reflectivity is important to a solar power plant's efficiency, the collectors must be kept free of dust, dirt, and other particulate matter. The frequency and method of concentrator cleaning are functions of the type of concentrator as well as the quantities of particulate matter in the atmosphere. However, it is expected that water will be a part of the cleaning system in some quantity.

C. CONSTRUCTION MATERIALS AND MANPOWER

Construction, operation, and maintenance of solar thermal power plants will, like other developments, require construction materials and manpower. Site preparation prior to plant installation is an important phase of plant construction and is to a degree dependent on topographic and geologic site characteristics. These site preparation activities may include: grading for collector bases and roads, road development, plant fencing, and the acquisition and transportation of materials required by

these activities. The materials, equipment, and manpower required for these activities will either come from adjacent communities or be imported from more distant parts of the region. Sites with these resources readily available will allow site preparation activities to be performed more quickly and economically than sites without them.

The frequency and type of maintenance required by solar thermal-electric power plants is currently unknown. However, several maintenance activities are expected. The collector's reflective surfaces will require cleaning. Drainage and service pathways may need clearing, repairs will be needed, and inspections made. Additional maintenance activities will be identified for solar thermal systems as they are developed.

D. LAND

The land area required by a typical 1-MWe solar thermal-electric power plant is approximately 10 acres. This is a function of the assumed insolation intensity, and the amount of electricity the plant is designed to generate. Lower average insolation requires more collectors and larger areas of land to produce the same amount of electricity. The solar thermal-electric system for the first engineering experiment will be a uniform size, regardless of where sited; the collector area will remain the same. Therefore, the average amount of electricity generated by the first experimental systems will vary from site to site as a function of meteorological conditions. The approximate 10-acre site for a 1-MWe plant contains all subsystem facilities and support structures such as maintenance buildings, access and service facilities. Additional land may be acquired for public information centers.

In addition to the acreage required for solar thermal power plants, there are other land characteristics that are important to siting, for example, adjacent land use. There are many industrial processes which produce effluents capable of eroding collector surfaces and blocking insolation. Industries utilizing highly flammable or explosive materials should also be avoided to avert damage to the plant from projectiles hurled by explosions.

The height of structures on adjacent land is also important. The site selection criteria included in the Program Opportunity Notice (PON) for a 10-MWe central receiver power plant developed by ERDA (now DOE) stipulate that: "Potential site locations should have an uninterrupted view to the south down to an angle of 10 degrees above the horizon extending from the local southeast to southwest direction . . . control of adjacent property through legal restrictions or outright acquisition may be necessary to satisfy this requirement" (Ref. 3). Specifications of this type will be developed by system designers for the system used in the first engineering experiment. Future land uses adjacent to the solar thermal power plant site should also be considered. A guarantee of unlimited "sun rights" into the future may become part of a new body of law dealing with solar energy technology (Ref. 4).

Other site characteristics are land form types. Solar power systems are sensitive to ground movement because of the precise focusing required. Therefore, sites proposed for them should be carefully evaluated to identify underlying or nearby geologic characteristics and their possible impacts. The most damaging geologic phenomena to be evaluated are earthquakes. Faults on or near the proposed site should be evaluated thoroughly. Active faults on the proposed site or near enough to cause damage to the plant may make that site unacceptable. In an Aerospace Corporation study, areas exceeding shaking of 0.26, or earthquakes of magnitude 7 on the Richter scale, were identified as unsuitable for solar thermal plants (Ref. 5, pp. 51-54).

Soil types are capable of increasing the impact that earthquakes have on surface structures. Alluvium is very unstable and tends to magnify earthquake shock waves. Other soil types to be avoided because of their instability are sand, dry lake sediments, expansive soils, and soils prone to liquefaction.

To achieve maximum efficiency, each collector in a field should be oriented to collect the maximum amount of sunlight. Thus, shading from the collectors themselves and from the surrounding terrain should be minimized. On sloping sites, the slope should face south, instead of north. On flat terrain shading can be overcome by spacing the collectors correctly, but enough flat terrain may not always be available.

It is not expected that sites with average surface grades greater than 20% will be considered for solar power plant sites; however, even on grades less than 20%, spacing and orientation difficulties may be present (Ref. 5, p. 36). Actually, it is not expected that slopes of over 10% would be acceptable for solar power plant sites. To obtain the required spacing, larger land areas will be needed in contoured topography than on flat sites. Other disadvantages of contoured sites are that plant installation may be more difficult and may require more grading and other site preparation. The less site alteration necessary, the fewer the environmental impacts from erosion, landslides, stream silting, flooding, and destruction of natural habitats and the lower the site preparation costs.

IV. PHYSICAL ENVIRONMENT

The previous section of this report dealt with the siting issues that arise as a result of the resource requirements of solar thermal-electric plants. In this section siting issues that arise as the result of meteorologic conditions will be identified. Meteorological or weather conditions must be taken into account to some extent in all development projects but solar thermal power plants have some unique sensitivities.

The concentrator is the subsystem most sensitive to meteorologic conditions in a solar thermal power plant. As described in the technology description section, they are designed to be relatively lightweight for tracking purposes and cost and, of necessity, are thin-walled and have fragile reflective surfaces. For maximum exposure to the sun, they should not be shielded by topography, vegetation or man-made structures. Some collector designs are protected by enclosures made of transparent materials. However, these structures are themselves sensitive to meteorological conditions.

Another subsystem that may be sensitive to meteorological conditions is the cooling system. Many cooling systems utilize evaporation, where efficiency is dependent on the characteristics of the atmosphere. The degree of this dependence is related to the cooling technology selected.

Solar thermal power plants must be designed to withstand meteorological conditions from two perspectives: operation and survival. For example, a plant will be designed to operate in winds up to a specified limit, and when winds exceed that threshold, the plant will be designed to discontinue operation but withstand the wind without significant damage. The percentage of time a solar thermal power plant must cease operation due to meteorological conditions may be traded against other site characteristics during site selection.

A. WIND

Wind may impact solar thermal-electric power plants in two important ways. First, its force and speed alone may be damaging. Secondly, it may carry particles of sand, dirt, and dust capable of scratching the reflective surfaces of concentrators. In many areas where wind is not obstructed by topography or vegetation, or where it is funneled through a topographic venturi, it can achieve high velocities. It is highly likely that solar thermal power plants may be located at such sites because of their requirement for terrain and vegetation which do not block insolation. Because of their size and shape, solar thermal collectors may induce high drag forces, and, as a result, they may be damaged by high winds.

The results of one central receiver system study indicate that winds of over 14 m/s (31 mph) should occur at the plant site less than 1% of the time (Ref. 6). This study further states that, "Plants of this central receiver system should withstand and operate in gusts up to 25 m/s

(55 mph), and survive without damage winds of 40 m/s (90 mph)" (Ref. 6). To do this, the collectors are designed to attain a less wind resistant, or stowage, position.

The operational and survival wind speeds quoted here for central receiver systems are exemplary only. They are intended to give the reader an understanding of wind/system interactions and a method of dealing with them. Design winds loads for each solar thermal plant will be determined during system design.

Information about wind patterns and speed are needed to provide system designers with design load data and to provide a basis for site evaluation. The type of information required is: prevailing wind direction and speed; recorded velocity extremes; gusts; and seasonal variation.

Besides collector structural damage, winds can damage reflective surfaces by abrasion from sand, dirt and dust particles. These surfaces may be made of reflective films, metals, and first or second surface glass and must retain their reflectivity to keep the plant operating effectively. Strong winds carrying sand and dirt may scratch reflective collector surfaces until they can no longer efficiently reflect sunlight.

In addition to data describing prevailing wind conditions, information on blow-sand conditions should be available at each respective site. The frequency of wind storms carrying sand, dirt, and dust should be indicated as well as the type and abrasive capabilities of these particulates (see Table 5).

B. PRECIPITATION

Rain, hail, snow, etc., affect solar thermal-electric systems in a variety of ways. This section identifies some of the problems these impacts could create.

Rain alone is not responsible for creating hazardous conditions to solar systems, but works together with topography and soil-slope stability. The evaluation of possible sites in areas receiving heavy rainfall should include a detailed analysis of soil type and slope stability. This evaluation is also indicated as necessary in the previous discussion of land suitability. Rain may cause landslides, erosion, and flash flooding. It is not expected that solar plants will be located near slopes steep enough to be concerned with landslides but sites susceptible to flash flooding, periodic flooding, and erosion should be identified.

In all candidate systems measures decreasing the impact of flooding and soil-slope slippage may be utilized. Some simple measures to improve a site with regard to flooding and slope stability are grading, the installation of drainage facilities and the revegetation

Table 2. Soil Susceptibility to Wind Erosion (Ref. 8)

Four ratings have been used to show the degree of susceptibility to wind erosion. Following each rating is shown the soil texture groups, presence of cobbles, and extent of exposure to wind.

| | |
|--------------------|--|
| <u>Slight</u> | Soils of moderately fine and medium textures and coarse texture soils with 40% or more cobbles on the surface. |
| <u>Moderate</u> | Soils of moderately coarse textures with 25 to 40% cobbles on the surface, and all soils that are protected from erosive winds. |
| <u>Severe</u> | Soils of moderately coarse and coarse textures with 10 to 25% cobbles on the surface, and all soils that are partially protected from erosive winds. |
| <u>Very Severe</u> | Soils of coarse textures that have less than 10% cobbles on the surface and that are exposed to erosive winds. |

of all disturbed slopes. The previously mentioned central receiver study (Ref. 6) developed site selection criteria that limit average annual rainfall to 750 mm (30 in.) and limit the amount of rain falling within a 24-hour period to 75 mm (3 in.). Criteria of this type will be developed during design.

Hail, falling on fragile reflective surfaces, may be capable of damaging them and rendering them useless as reflectors. Both hail and snow may also significantly affect solar collectors due to their weight alone. Tracking mechanisms may not be strong enough to operate when collectors are filled with hail or snow, and the support structures may give way in these conditions unless designed to bear their weight. Additionally, the maintenance costs of keeping collectors free of hail and snow, if necessary, may be high. Data indicating hail and snow characteristics should be collected by either system designers or site proposal teams prior to final site selection.

The central receiver study indicates that a solar thermal power plant should survive 20 kg/m^2 (5 lb/ft^2) of snow at a deposition rate of 0.3 m (1 ft.) in 24 hours. It should also survive freezing rain and ice deposits in a layer 50 mm (2 in.) thick (Ref. 6). Again, these figures are exemplary only. Data describing precipitation extremes and averages should be available to system designers at each prospective site for final site selection.

C. TEMPERATURE AND AIR QUALITY

Every area has seasonal temperature extremes, temperature differences between day and night, and average, yearly, seasonal, and daily temperature changes. The goal of solar thermal-electric power plant design is to construct plants which will continue to function efficiently in various environmental conditions. The most environmentally sensitive part of collectors are the reflectors. Any warping or distortion of reflective surfaces would decrease overall plant efficiency. The central receiver system studied by Sandia describes operational ambient temperatures as -30°C (-20°F) to $+50^{\circ}\text{C}$ ($+120^{\circ}\text{F}$) (Ref. 6).

The cooling subsystem may also be impacted by temperature, especially if it utilizes evaporation. The efficiency of evaporation is a function of ambient air temperature and humidity as indicated in previous discussions. For example, natural draft wet cooling towers perform best in areas with high relative humidities and mild temperatures, and perform poorly in regions with low humidities and high ambient temperatures.

Air pollutants may impact the reflective surfaces of collectors in several ways. Particulate matter deposited on them will block insolation, chemical reactions induced by these pollutants may damage these fragile surfaces, and poor air quality can block some direct insolation from reaching the earth's surface.

Air pollution is regulated by federal, state and local air quality protection agencies. To ensure air quality protection these agencies monitor the air quality, record the kinds and quantities of pollutants found in the air and make this information available to the public.

V. SOCIAL/INSTITUTIONAL ISSUES

Up to this point the issues identified have been concerned with the physical needs and capabilities of solar thermal-electric systems. Since electric utilities provide a valuable commodity to a larger number of people, they must operate in a reasonable and safe manner while meeting their customers' needs. Solar thermal-electric power generation, a new technology, must prove itself in these regards. This section deals with issues which may result from the integration of solar thermal-electric systems into the local social and institutional structure.

A. LEGAL-REGULATORY

The legal-institutional environment is composed of regulatory and organizational requirements that delineate procedures minimizing disturbance to neighboring developments, the natural environment, and the general public which may accrue from the construction and operation of new developments. Regulatory agencies and regulations differ from site to site because the subjects of regulations (for example, natural resources, public health, and economic development) differ. However, there are broad categories of regulations and regulatory agencies that are common to all sites and there are development projects that require the involvement of specific types of regulatory agencies at all sites. Table 6 indicates some of the agency types which may be involved in the development of solar thermal-electric power plants.

Table 3. Regulatory Issues

| | |
|---------------------------------|---|
| Land Use | Federal Lands State Lands Regional, County and City land use plans Municipal zoning ordinances |
| Construction | Building Codes |
| Safety of Personnel | Occupation health and safety agencies |
| Pollution Control | Air and Water Quality Agencies Health Agencies |
| Wildlife Protection | Fish and Game Agencies |
| Cultural Resource Protection | Historical Preservation Agencies |
| Electric Utility | Public Utilities Commissions Federal Department of Energy State Energy Commissions |
| Environmental Assessment | Federal Environmental Legislation State environmental legislation |

The body of law and regulation is important to solar thermal-electric power plant siting because of the possibility that some regulations may preclude solar development. First, regulations can prevent the acquisition of construction and operation permits. Second, regulatory agencies can attach conditions to the permits which may cost the developer more than the benefits he expects to receive from his development. Third, the time required for permit acquisition may be too lengthy and procedures too complex for the time and money resources available.

Solar thermal-electric power technology is new, and, therefore, no regulations specifically governing solar thermal power plant activities exist. Regulatory agencies are unfamiliar with solar plant processes and consequently are unsure which regulations may apply to them. Therefore, the first experimental solar systems may have to deal with conditional permits and time delays beyond those required of conventional development projects.

Because of possible regulatory time delays and conditional permits, regulatory agencies experienced in handling various types of development projects and sites with proposal teams who have experience in dealing with regulatory agencies may be preferred to sites without this experience. Alternatively, a site with relatively simple regulatory procedures may be preferable to a site with complex regulatory requirements, regardless of the experience of the regulatory agencies and proposal teams. For example, sites with limited water supplies may have regulations covering all possible aspects of water use and water quality protection as opposed to sites with overabundant water supplies whose regulatory agencies are enforcing only basic pollution control measures.

B. COMMUNITY/REGIONAL SUPPORT

Solar thermal-electric power plants will of necessity interact closely with the communities they serve. The electricity they generate must be integrated into the distribution system of the local utility and be available during times of peak demand to be of greatest value. The plants must comply with local regulatory requirements and will require services such as roads, water, sewer, and telephone. They may require manpower and materials for site preparation, construction, and operation, and may need to share transportation facilities with local citizens.

Because of the diversity of these interactions, it is very important that local public opinion be in favor of solar thermal power plant development. Public opinion has a strong influence on government and regulatory agencies. It can either delay or accelerate regulatory processes, and can cause publicity to be either positive or negative. Public opinion is important to all prospective solar thermal-electric power plants but may be of even greater importance to the first engineering experiment because of the various functions the experiments must perform.

The first solar thermal-electric experimental power plants are primarily intended to provide the developers of solar thermal-electric technology with important performance data that will be utilized to improve plant performance. The production of utilizable electricity is a secondary goal. It may take several years for the plants to attain acceptable efficiency. In the interim, plant performance is open to public scrutiny, which could lead to adverse publicity. This may injure development programs, preventing the required research to achieve maximum efficiency. Therefore, a site within a community positively inclined toward plant development or with a need for the type of generating capability a solar thermal power plant can provide may prove to be a more beneficial site than one in a community without this inclination or need.

While adverse publicity is clearly a disadvantage, the lack of public information concerning solar thermal-electric technology may also hinder its development. A third function of the first experimental solar thermal-electric power plants is to demonstrate and publicize the technology and its possible applications to those who may have need for an electrical generating plant of this type and an interest in utilizing it. An extremely remote site with a dearth of communication media, such as newspapers, newsletters, radio or television coverage, may not perform this publicity function as well as a site with access to these facilities. Convenient access may also be an important aspect in community integration. As in the saying, "a picture is worth a thousand words," public inspection may do more to popularize solar thermal-electric power than many other aspects of the plant.

Other important site conditions relating to community relationships are the availability of community resources to support solar thermal-electric power plants, their stability, experience, and innovation. Close interaction between solar thermal power plants and the communities they serve may maximize both the plant's utility to the community and plant operating efficiency by ensuring power is delivered when needed, services required by the plant are provided reliably, and adverse plant impacts on the community are minimized. Disadvantages may result from close interaction if the community is unable to provide the support solar thermal power plants require.

Communities with experience managing and regulating development projects may be better equipped to interface with solar thermal power plants than communities without this experience. Experienced communities have dealt with regulatory agencies and officials, are familiar with the procedures and time scales involved, have existing management procedures for large development projects and management personnel familiar with them. However, also of importance are the flexibility of management procedures and the diversity of development projects the community has encountered. Management procedures developed for specific types of development, although well understood by all community management personnel, may not facilitate the management of new development projects. A highly specified and structured management procedure may even hinder the management of new development types by trying to force management procedures to fit development projects they were not designed to encompass.

VI. SOLAR THERMAL POWER PLANT IMPACT

Previous sections of this report have discussed site attributes from the perspective of their acceptability to solar thermal power plant development. In this section, solar thermal power plant activities will be discussed from the perspective of possible impacts on their sites. A site may be considered inadequate for solar thermal development if the plant's impacts are significant and cannot be mitigated. Solar energy systems may impact the environment less than any of the conventional electricity generating technologies. However, as a new technology, there may be impacts which have not yet been identified. As solar thermal technology is developed, it will be important to these environmental impacts and determine their significance.

A. ECOLOGICAL IMPACT

Every development project disrupts the flora and fauna on and around its site. The degree to which this disruption is significant depends on the rarity of the species, and whether the site has been previously disturbed.

Prior to final site selection, an ecological assessment indicating the impact the plant may have on the wildlife habitat of the area must be identified. Some species of plants and animals are protected because they are rare. These species are listed on federal and state endangered species lists. Collection of ecological data should include all species on the proposed site and in the immediate area emphasizing those included on endangered species lists and any species in the area which have been nominated for inclusion. A site containing endangered species could not be utilized for solar thermal development unless major steps are taken to protect them.

Once construction is complete and the plant is operating, there may be additional ecological impacts. The plant subsystems including cooling will increase shading and require washing which may encourage the growth of different types of vegetation than those existing previously. This may in turn attract new species of animals and birds and the intrusion of new species into an area can significantly impact present ecology. It is expected that the growth of vegetation between collectors will be fairly carefully controlled, thus reducing the significance of this impact. Additionally, chemical solvents may be used to clean collector surfaces which may poison some species. The on-site vegetation, already heavily impacted by construction of the plant, may not constitute a significant impact in this regard. There may not be any on-site vegetation once the plant is complete.

The quantity and toxicity of the transport fluids and cleaning solvents utilized by solar thermal-electric plants will depend on the plant design. However, they are expected to be less environmentally damaging than those used in many conventional residential and commercial

operations. In addition, all liquid waste disposal will be regulated by water quality control agencies, and the plant will be designed to minimize the possibility of accidental releases and pipeline leaks. However, to ensure ecological safety, the pathways inadvertant releases would travel through the environment and sensitive organisms that could be impacted by these releases should be identified at each prospective site.

Another potential impact is noise. Solar thermal electric plants are expected to produce less noise than fossil fueled plants of equivalent sizes since they do not involve combustion. The significance of this impact depends on the final design and size of the engines and the proximity of the site to people and ecological systems sensitive to noise. In sensitive areas, noise mitigation measures could be implemented.

B. MICROCLIMATE AND AIR QUALITY

The primary resource that solar thermal power plants require to operate is sunlight or insolation. Insolation is utilized as fuel, and, unlike the fuels utilized by conventional electricity generating power plants, no mining is required, no waste products are produced, no air contaminants are released, and no transportation problems result from its use. These are the major impacts of fossil-fueled and nuclear power plants. In comparison, solar thermal-electric power plants seem to have few impacts that can be directly attributed to their fuel source.

Change of an area's solar radiation budget is a potential impact peculiar to solar thermal power plants. This would result from the concentration and collection of a large amount of sunlight in an area instead of allowing it to be dispersed naturally. A change in the radiation budget may influence the microclimate of an area. Presently, investigations are being performed to determine the degree that climatological conditions may be impacted by changes in the radiation budget due to solar thermal power plants. Plant size is expected to be an important factor. The impact of a 1-MWe solar power plant with regard to radiation budget and climatological changes is expected to be insignificant.

Local climatology may also be influenced by cooling. The type of cooling equipment and ambient temperature together dictate the size and height above ground of vapor plumes, the severity of fog, which may block insolation, icing and augmentation of rain and snow. However, these impacts would occur in any industry utilizing a cooling technology.

The protection of air quality is represented by the federal Clean Air Act administrated by the Environmental Protection Agency. Many state and local agencies have adopted more stringent standards. Solar thermal power plants must comply with the regulations of the local air quality protection agency with jurisdiction over its site. If a local

air quality protection agency does not exist, the regulations of the EPA are applicable.

Solar thermal power plants are expected to impact air quality most significantly during construction when heavy equipment grading the site and installing the collectors will raise dust and exhaust combustion products into the atmosphere. If the plant has a fossil fueled component for operation when insolation is unavailable the engine exhaust will also impact air quality. Although neither of these sources are expected to represent a significant impact on the area's air quality, however they must be evaluated by both the site participant and the air quality protection agency with jurisdiction to ensure local air quality will not be significantly degraded by plant activities. Compared to a conventional facility generating 1MWe the operation of a 1MWe solar thermal-electric power plant represents a net improvement in air quality.

C. WATER USE

To coordinate a solar power plant's water use with that of the community, the use patterns of the surrounding area should be ascertained. Regardless of the source, natural hydrology (rivers, lakes, and aquifers) or municipal water supplies, it must be determined that water use in the plant should not overburden the existing local water system and that plant water requirements will be satisfied even in times of drought. To some extent water use is dependent on the type of community. Agriculturally based communities have seasonal water use patterns, while industrial, commercial, and residential communities have daily peaks. Each of these users may also require water of different qualities.

Water use compatibility between solar plants and communities is also dependent on the specific uses of the water. The introduction of harmful chemicals into a water system by solar plant activities may not be allowed by local water agencies. Water treatment facilities and water quality regulations vary from site to site. Some communities have minimal treatment facilities and regulations while others have very sophisticated treatment facilities and stringent regulations. Usually, sophisticated equipment and regulations are found in areas with limited water supplies. In these areas water treatment of some kind is a requirement prior to return to the reservoirs. It will either be treated by the user or in a community waste water treatment facility. Solar thermal power plants must coordinate their disposal of waste water with the local regulatory agencies in all areas but particularly in the areas where water is in limited supply.

If the natural hydrology is the source for water uses in the area, great care must be taken by solar power plants to prevent depletion of the resource, lowering of water quality, or alteration of hydrologic systems that may adversely impact the natural environment as well as other water users. Local regulatory agencies influence the configuration of water use and disposal to such a degree that solar thermal power plants must coordinate with them from a very early stage in site selection. Compliance with these agency regulations ensures more than any other single measure that the plant is compatible with an area's estab-

lished water use patterns because their regulations take into account the quantities and qualities of water available in local sources, the peaks of use, and environmental protection.

D. LAND USE

The primary impact of land used for solar thermal-electric power plants is compatibility and competition with existing and planned land uses for the sites themselves and for rights-of-way for access roads. A solar plant that is compatible with or well integrated into a community's existing land use patterns will serve the community and achieve success much sooner than plants which are not.

Successful integration into an area's land use patterns can be achieved in several ways. One way is to follow zoning ordinances and land use trends. Most communities have land use plans in which specific land uses are designated in specific areas or zones. In California, municipalities are also required to develop General Plans to shape their future growth. Included in General Plans are land use elements that attempt to direct the physical growth of municipal areas to maximize their aesthetics as well as their economics. Solar thermal power plants must comply with General Plans, in cities and counties that have them.

An awareness of local zoning or planning agency concerns may facilitate solar thermal power plant integration into a community immeasurably. It is expected that solar thermal power plants will require zoning changes on most sites. As in the case described for water use, sensitivity to the requirements of local agencies ensures developers of a clear right to develop solar power plants in an area and guards against delays due to unforeseen regulatory requirements.

E. COMMUNITY

Power plant construction, operation, and maintenance activities may have significant impacts on the community. The degree to which these activities may impact communities is dependent on the type of community and whether manpower, equipment, and materials will be obtained from within the community or whether they will be imported from surrounding areas. A community with a work force possessing appropriate skills, adequate quantities and qualities of materials and equipment for solar power plant development will be least impacted by solar thermal power plant activities. They are more likely to be impacted favorably, if impacted at all, because of increased business from plant activities. Because the workers are in residence, city services are already accommodating them and do not require expansion to maintain adequate service.

A community without these resources may be impacted significantly. The importation of people, materials, and equipment will create more traffic, add to the demand on the water supply and sewage treatment facilities, make additional demands on electric utilities, and may drive plant costs up. If plant employees move their families into the area, schools, fire and police protection, and housing may also be strained. The significance of these impacts vary with the size of the community, the

distance between the solar power plant site and the community, and the willingness and capability of the community to meet solar thermal power plant requirements.

F. SAFETY

During plant construction, the safety of the general public would be threatened in ways similar to the construction of a fossil-fueled generating power plant, however, on a smaller scale. It is during the operation of solar thermal-electric power plants that some safety issues arise which are unique to solar plants. The first issue to be discussed is concerned with the consequences of a solar collector focusing sunlight on people, buildings or other objects outside plant boundaries.

A typical parabolic concentrator in a distributed receiver system has a focal distance of approximately 6 m (20 ft) and concentrates effectively only when pointed at the sun. Hence, there should be no safety hazard due to improper alignment. However, the heliostats in a central receiver system may have focal distances of several hundred feet. The reflected sunlight from a single heliostat is only slightly concentrated, but eye damage is a potential hazard at the focal point of a misaligned heliostat.

To alleviate concern over this issue, sites for central receiver plants may require guarded buffer zones. More study is required on the potential hazard within the field area. There is also a secondary focal point at a greater distance from a heliostat or concentrator. However, intensity at the secondary focus is much reduced, similar to the glare reflected from glassy surfaces.

At certain angles the heliostats of a central receiver plant may reflect light or glare, which may distract or temporarily blind operators of automobiles and aircraft in extreme cases, causing them to lose control. However, glare from solar thermal power plants has not been studied in enough depth to be sure how strong the glare might be, at what angles and distances it is disrupting, and exactly how disrupting it really is. This indicates that central receiver solar thermal power plants with a glare hazard should not be sited adjacent to freeways or airports unless there are mitigating factors that eliminate the glare uncertainty. Glare may also have impacts unrelated to safety. For aesthetic or nuisance reasons, glare may be an unwanted impact of solar thermal-electric plants in close proximity to communities.

The safety of the general public may also be threatened by toxic chemicals if any are used as transport fluids. All liquid waste disposal will be regulated by water quality control boards to ensure environmental and public health protection; therefore, safety hazards from these chemicals would only result from accidents or pipe leaks. The degree of threat posed by toxic plant chemical accidents depends on the specific chemicals used and the processes within the plant in which they are used. As a siting criterion, the probable pathways of inadvertent toxic chemical releases should be analyzed at each prospective site, both airborne and waterborne.

Water pollution control regulations prevent the disposal of contaminated water outside plant boundaries. If these regulations are complied with, there should be no impact on the ecology outside plant boundaries due to cleaning solvents. However, accidental releases and pipeline leaks must not be discounted.

REFERENCES

1. Proceedings of Small Power Systems Solar Electric Workshop: Vol. II. Invited Papers, Aspen, Colorado, October 10-12, 1977. Department of Energy DOE/JPL-1060-78/1 and JPL Publications 78-10, 1978.
2. Walden, Phillip C., An Overview of Power Plant Options for the First Small Power System Experiment: Engineering Experiment No. 1, JPL Internal Document 5103-38, 1978.
3. Central Receiver Solar Power 10-Megawatt Electric Pilot Plant Project Site Selection, Program Opportunity Notice (PON), Energy Research and Development Administration, Washington, D.C., closing date Sept. 1976, p. 4.
4. Thomas, William A., Miller, Alan S., and Robbins, Richard L., Overcoming Legal Uncertainties About Use of Solar Energy Systems, American Bar Foundation, Chicago, 1978.
5. Solar Thermal Conversion Mission Analysis - Area Definition and Siting Analysis, Vol. V, The Aerospace Corporation, El Segundo, CA, Jan. 1974.
6. Conceptual Design of Advanced Central Receiver Systems, Sandia Laboratories, Livermore, CA, Sept. 1977 (A Request for Proposal submitted to the Department of Energy).
7. Brooks, Frank L., Progress Report: Coachella Valley Wind Erosion Problem, at the request of Coachella Valley Soil Conservation District, Dec. 1967, p. 25.

BIBLIOGRAPHY

California Power Plant Siting Study, prepared for Resources Agency, State of California, and U.S. Atomic Energy Commission by Holmes and Narver, Inc., Anaheim, CA, in association with Danes and Moore, Los Angeles, CA, May 1973.

Caputo, Richard S., An Initial Study of Solar Power Plants Using a Distributed Network of Point Focusing Collectors, 900-724, EM 342-308, p. 23, Jet Propulsion Laboratory, Pasadena, CA, July 1975 (JPL internal document).

Central Receiver Solar Thermal Power System Phase 1, Quarterly Progress Report (Final) for Period Ending March 13, 1976, Martin Marietta Corporation, Denver, CO, Oct. 1976.

Environmental Development Plan (EDP), Solar Power Systems 1977, Energy Research and Development Administration, Mar. 1978.

Frigerio, N.A., et al., SITE: A Methodology for Assessment of Energy Facility Siting Patterns, Argonne National Laboratory, Argonne, IL, Aug. 1975.

Fujita, T., El Gubalawi, N., Herrera, G., and Turner, R. H., Projection of Distributed-Collector Solar-Thermal Electric Power Plant Economics to Years 1990-2000, DOE/JPL-1060-77/1, JPL Publication 77-79, J Thermal Power Systems Research and Development Project, Jet Propulsion Laboratory, Pasadena, CA, Dec. 1977.

Goldsmith, Martin, Siting Nuclear Power Plants in California, The Near-Term Alternatives, July 1973.

Hunke, Robert W., Methodology for Site Selection of a Solar Total Energy Large Scale Experiment, Sandia Laboratories (Solar Total Energy Program Division), Albuquerque, NM, Mar. 1977.

New York Power Pool Statewide Site Selection Guide, New York Power Pool, Nov. 1976.

Robbins, Richard L., "Law and Solar Energy Systems: Legal Impediments and Inducements to Solar Energy Systems," Solar Energy, Vol. 18, pp. 371-379, 1976.

Sears, R. D., et al., Preliminary Environmental Assessment of Solar Energy Systems, Lockheed Missiles and Space Company, Incorporated, Huntsville, AL, Aug. 1977.

Systems Analysis of Solar Energy Programs, Mitre Corporation, Dec. 1973.

Walden, Phillip C., An Overview of Power Plant Options for the First Small Power System Experiment: Engineering Experiment No. 1, JPL Internal Document 5103-38, 1978.